

New and reinterpreted observations on *Actias luna* (LINNAEUS, 1758) (Lepidoptera: Saturniidae)

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Abstract: Previously unpublished observations and reinterpretations pertaining to *Actias luna* are described. These include new parasitoid records of *Anastatus redivivii* (Hymenoptera: Eupelmidae) attacking the eggs in Texas, *Cotesia schizurae* (Hymenoptera: Braconidae: Microgastrinae) parasitizing larvae in Texas, cocoon placement above ground by spinning larvae, pupae aestivating during hot and dry summers in Texas, a new hostplant record of *Larix laricina* (Pinaceae) in Manitoba, wing pattern defenses, and a molecular genetics explanation of morphological aberrations reported from Georgia in 1975.

Key words: *Actias*, *Anastatus*, *Cotesia*, *Hox genes*, *Larix*, *luna* moth, pupal aestivation.

Neue Beobachtungen und Interpretationen zu *Actias luna* (LINNAEUS, 1758) (Lepidoptera: Saturniidae)

Zusammenfassung: Bisher unpublizierte Beobachtungen und Neuinterpretationen zu *Actias luna* werden publiziert. Dazu gehören neue Parasitoidenberichte wie *Anastatus redivivii* (Hymenoptera: Eupelmidae) an den Eiern in Texas oder *Cotesia schizurae* (Hymenoptera: Braconidae: Microgastrinae) parasitierend in Raupen in Texas, weiterhin Beobachtungen zum oberirdischen Kokonbau in den Futterpflanzen, die Übersommerung (Aestivation) der Puppen in trocken-heißen Sommern in Texas, ein neuer Raupenfutterpflanzen-nachweis auf *Larix laricina* (Pinaceae) in Manitoba, Überle-gungen zur Feindabwehr durch das Flügelmuster sowie eine genetische Erklärung für morphologische Aberrationen, die 1967 in Georgia beobachtet wurden (1975 publiziert).

Introduction

The general public in Canada and the United States probably recognizes the luna moth (*Actias luna* (LINNAEUS, 1758)) more than any other lepidopteran (d'ABRERA 1998: 56). In the North American popular culture, images of this exquisite moth appear frequently in art, nature magazines, wall calendars, jewelry, postage stamps, first day covers, patches, greeting cards, children's books, and so forth. Although common and wide-ranging, a lot remains to be learned about the biology of this insect. This paper presents several unrelated observations that are new or reinterpreted pertaining to this species.

The shade of green on the wings is highly variable, but these colors are predictable based on sex, season, and geography. Males have white bodies tinged with yellow and darker yellowish green wings (Fig. 1), compared to females, which have snow white bodies and lighter and more bluish green wings (Fig. 2). Specimens from the Deep South (the Carolinas, Georgia, and the states bordering the Gulf of Mexico) are more intensely colored than the paler ones from Canada, New England, and the

Great Lakes region. Spring specimens that overwintered as pupae have more maroon on the outer edges of the wings than ones that did not enter diapause. Additionally, some specimens have a powdery blue band inside the maroon edges, as shown here in Figs. 1-3 and by FERGUSON (1972: pl. 16, figs. 3-5), d'ABRERA (1998), and BOUSEMAN & STERNBURG (2002).

Seasonal flight times and aestivation

In the literature, *Actias luna* is stated to be univoltine in Canada and the northern United States, but bivoltine in the central and southern United States, with an additional third brood in the Gulf States, and possibly multivoltine in central and southern Florida (COLLINS & WEAST 1961, FERGUSON 1972, COVELL 1984, LAPLANTE 1985, WAGNER 2005). In southern Texas there is certainly time for four broods between the winters, but the species generally flies in late February or March, again in May, and then again in September and October. The "missing" brood of July and August is apparently due to a pupal aestivation during the hottest and driest part of the summer. I observed this several years using stock from Tennessee and Texas. I have encountered the same pattern of aestivation in captive cultures of *Antheraea polyphemus* (CRAMER, 1775) in southern Texas. In July, August and September the weather is usually very hot and dry, and exposed larvae would be less able to survive these extremes than pupae. Aestivation has never been reported, as far as I know, for *Actias luna* or *Antheraea polyphemus*. If aestivation occurs in central and southern Florida, where summer rainfall is more reliable, I suspect it to be less common.

In March and April of 2008 in San Antonio, I reared a brood of *Actias luna* from eggs from a female taken at Pipe Creek, Bandera County, Texas. Although one male emerged in early May, the other ten pupae aestivated during the hot dry summer, and the remaining adults from this spring 2008 rearing did not emerge until February and March 2009 (Figs. 2, 3). These cocoons were kept in an outdoor cage for almost a year, and were sprayed with water routinely during that time. I reared another brood (Figs. 1, 4) in San Antonio in spring 2006 from eggs received from eastern Tennessee, and aestivation was also observed for the majority of those. Voucher specimens of *A. luna* that had a pupal aestivation were deposited in McGuire Center for Lepidoptera & Biodiversity and Texas A&M University Insect Collection.

Parasitoids

Hymenoptera: Eupelmidae. Until now, no particular primary parasitoids have been recorded from the eggs of *Actias luna* (see PEIGLER 1996: 51). Although the moth is very common in many regions, finding eggs in nature requires a lot of searching, so is rarely successful. The following record is not surprising, since the same parasitoid has been reared from eggs of *Antherea polyphemus* and other Saturniidae.

Anastatus reduvii (HOWARD, 1880). A mass of eight eggs of *A. luna* was found by R. S. PEIGLER on the underside of a leaf of sweetgum (*Liquidambar styraciflua* L.), near Ratcliff, Houston County, Texas. The eggs were kept in a plastic container, and each egg yielded a single parasitoid on 4. x. 2003. The parasitoids were identified using the revision by BURKS (1967), but since all of the specimens of this rearing were males, the identification to species-level remains tentative.

Hymenoptera: Braconidae: Microgastrinae. Thirteen larvae of various instars of *Actias luna* were collected on sweetgum trees on 6. x. 2012 by R. S. PEIGLER and three of his students along Highway 1375, Walker County, Texas, near Stubblefield Lake Recreation Area. One larva yielded 33 larvae of *Cotesia* that spun cocoons on the back of the larva, and 33 adult wasps of both sexes emerged 21.–22. x. 2012.

The identification of this parasitoid was given tentatively as *Cotesia schizurae* (ASHMEAD, 1898), recorded to parasitize *Schizura* (Notodontidae). I have often collected larvae of *Schizura* on sweetgum at that locality. *Cotesia schizurae* keys very close to *Cotesia hemileucae* (RILEY, 1881) (S. R. SHAW, personal communication), a parasitoid known to attack hemileucine saturniids (PEIGLER 1996).

Voucher specimens of the *Cotesia* were deposited in University of Wyoming Insect Museum, and *Cotesia* and *Anastatus* in Texas A&M University Insect Collection.

Hostplants

A mature larva of *Actias luna* was collected on larch (*Larix laricina* (du Roi) K. KOCH) by Donald C. HENNE in Manitoba in an area where the moth is quite common and normally feeds on paper birch (*Betula papyrifera* MARSH.). HENNE (personal communication) did not recall the exact locality or year. This new record of *A. luna* feeding on a conifer is not unexpected, because others in this group are known to accept conifers, such as *Graellsia* on *Pinus* in Europe and several species of *Actias* in China feeding on *Larix*, *Pinus*, and *Cedrus* (NAUMANN 2006, WU & NAUMANN 2006). Phylogenetically, *Pinus* is considered closest to *Larix* and *Cedrus* within the Pinaceae (PHILLIPS & RIX 2002).

One first-instar larva of *Actias luna* was collected 6. x. 2012 on *Liquidambar styraciflua* on Highway 1375, Walker County, Texas. In San Antonio, more than 200 km west of the natural range of *L. styraciflua*, that larva was

reared to maturity on Chinese sweetgum (*Liquidambar formosana* HANCE). A female moth emerged 12. v. 2013, and is in the collection of Stefan NAUMANN in Berlin. Another non-native, alternate hostplant for *A. luna* is mango (*Mangifera indica* L.). I observed that captive larvae of *Actias luna* freely accept leaves on potted seedlings of mango, a tree that is also used by *Actias selene* (HÜBNER, 1806) in tropical Asia (D'ABRERA 1998: 58).

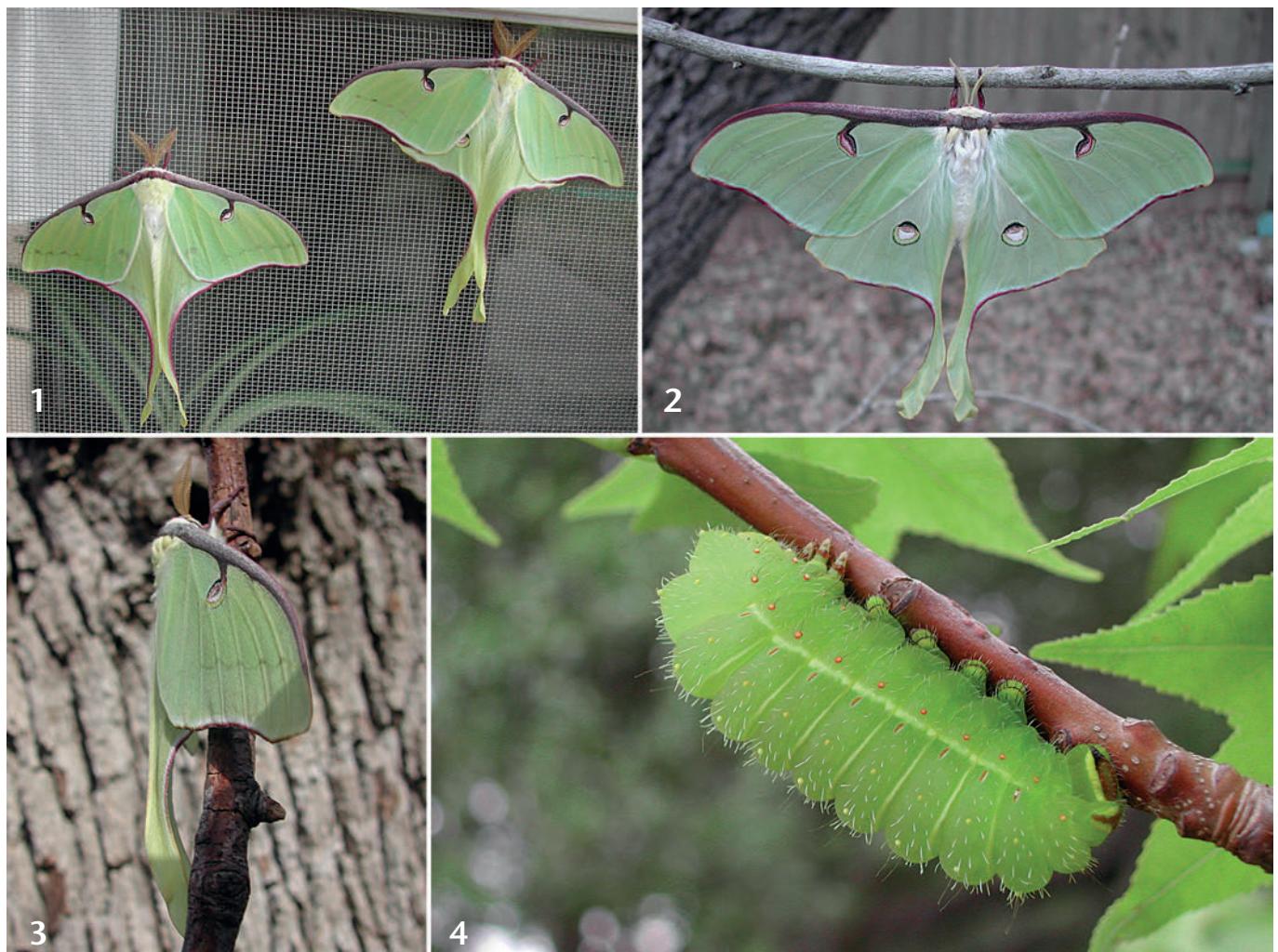
Although common in central Texas as far west as Kimble and Uvalde counties, common hostplants of the Southeast such as sweetgum (*L. styraciflua*) and persimmon (*Diospyros virginiana* L.) do not range that far west (CORRELL & JOHNSTON 1979). I found that captive larvae always reject black persimmon (*D. texana* SCHEELE) if offered this plant, which is common in central Texas, but quite different from *D. virginiana*. Populations of *A. luna* in central and west-central Texas are therefore ostensibly restricted to Juglandaceae in their foodplants. The native and common pecan (*Carya illinoensis* (WANG.) K. KOCH) is undoubtedly the primary food in these regions. Although there are no records for *A. luna* feeding on them, other hickories and walnuts probably also serve as hosts. For example, Arizona walnut (*Juglans major* (TORREY) HELLER) ranges eastward into the Edwards Plateau (CORRELL & JOHNSTON 1979), a region called "the Hill Country" by all Texans. Arizona walnut is closely related to black walnut (*J. nigra* L.), a favorite host of *A. luna* in eastern North America.

Cocoon placement by spinning larvae

The literature on North American saturniids is replete with statements that cocoons of *A. luna* are spun on the ground among dead leaves, or when spun in the leaves up in the host tree, the cocoons fall to the ground with those leaves in the autumn (e.g., ROBERTSON-MILLER 1912, STRATTON-PORTER 1912, FERGUSON 1972, COVELL 1984, BOUSEMAN & STERNBURG 2002). COLLINS & WEAST (1961) echoed the aforementioned comments, but added that cocoons are sometimes found attached to the sides of logs. As far as I am aware, there are no reports of cocoons remaining up in the host tree, or being attached to twigs of the tree. However, on several occasions I found cocoons of *A. luna* attached to sweetgum twigs, about 1–1.5 m above ground, on small trees, usually within a few cm of the main trunk. These observations were made in Savannah, Georgia; Colleton County, South Carolina; and Walker County, Texas. Voucher specimens of these cocoons, still attached to their twigs, were deposited in the McGuire Center for Lepidoptera & Biodiversity.

Wing pattern defenses

I agree with HOWSE & WOLFE (2011, 2012) that the eye-spots on the forewings of *Actias luna* probably appear to be berries or flower buds attached to a stem (the purple costal margin) to some predators. However, viewing a perched specimen from the perspective shown in my



Figs. 1–4. *Actias luna*, spring form from southern states. **Fig. 1:** Males from eastern Tennessee. **Fig. 2:** Female from Bandera County, Texas. **Fig. 3:** Male from Bandera County, Texas. **Fig. 4:** Mature larva from eastern Tennessee on sweetgum (*Liquidambar styraciflua*).

Fig. 3 also calls to mind a small mammal, with the eye-spot representing the eye, and the thorax representing the nose. If this image could be interpreted as the head of a rabbit, the tails of the hindwings could represent the floppy ears. As discussed by HOWSE & WOLFE, birds do not have the time or mental capacity to interpret appropriate sizes of such images. Although the wing pattern of *A. luna* appears to be fairly simple, it undoubtedly presents a diverse suite of images for various predators to interpret.

Genetic explanation for aberrant morphology

BROWN (1975) described two specimens of *Actias luna* collected at lights at Neels Gap, Lumpkin County, Georgia, a male on 30. v. 1967, and a female collected in early June 1967. In the male, the left antenna was normal, but the right antenna was only 1.6 mm long with slight pectinations. Additionally, it had a normal antenna arising from the left side of the prothorax. The female had a normal left antenna, but the right antenna was replaced by a tibia and tarsus. Unfortunately, the specimens were kept in BROWN's personal collection.

Recent studies in developmental biology provide an explanation for these bizarre aberrations (FREEMAN & HERRON 2007: Chapter 19). In arthropods, homeotic genes called *Hox* genes control this type of development. When these genes are knocked out by a mutation, structures may appear that normally occur on another segment. For example, in *Drosophila*, mutations in the *antp* gene can cause a leg to form where an antenna should be. As stated by FREEMAN & HERRON (2007: 728), when the map molecules are lost, cells can form structures appropriate to the wrong location on the body.

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